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Context awareness for maintenance decision making: A diagnosis and prognosis approach

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ABSTRACT

All assets necessarily suffer wear and tear during operation. Prognostics can assess the current health of a system and predict its remaining life based on features capturing the gradual degradation of its operational capabilities. Prognostics are critical to improve safety, plan successful work, schedule maintenance, and reduce maintenance costs and down time. Prognosis is a relatively new area but has become an important part of Condition-based Maintenance (CBM) of systems.

As there are many prognostic techniques, usage must be acceptable to particular applications. Broadly stated, prognostic methods are either data-driven, rule based, or model-based. Each approach has advantages and disadvantages; consequently, they are often combined in hybrid applications. A hybrid model can combine some or all model types; thus, more complete information can be gathered, leading to more accurate recognition of the fault state. In this context, it is also important to evaluate the consistency and the reliability of the measurement data obtained during laboratory testing activity and the prognostic/diagnostic monitoring of the system under examination.

This approach is especially relevant in systems where the maintainer and operator know some of the failure mechanisms with sufficient amount of data, but the sheer complexity of the assets precludes the development of a complete model-based approach. This paper addresses the process of data aggregation into a contextual awareness hybrid model to get Residual Useful Life (RUL) values within logical confidence intervals so that the life cycle of assets can be managed and optimised.

1. Introduction

Assets are complex mixes of complex systems with more complex level of interaction. Each system is built from components which, over time, may fail. When a component does fail, it is difficult to identify it because the effects or problems that the failure has on the system are often neither obvious in terms of their source nor unique. The ability to automatically diagnose problems that have occurred or will occur in systems has a positive impact on minimising risk for safety, hazard, shutdown and slowdown [9,19].

Previous attempts to diagnose problems occurring in systems have been performed by experienced personnel with in-depth training and experience [20]. Typically, these experts use available information recorded in a log. Looking through the log, they use their accumulated expertise to link incidents to the problems that may be causing them. If the incident-problem scenario is simple, this approach works fairly well, but if the incident-problem

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scenario is complex, it becomes very difficult to diagnose and correct failures associated with the incidents [9].

Computer-based systems are now being used to automatically diagnose problems to overcome some of the disadvantages associated with relying on experienced personnel [21]. Typically, a computer-based system utilises a mapping between the observed symptoms of the failures and the equipment problems using techniques such as table look ups [22], symptom-problem matrices, and rules of thumb [23]. These techniques work well for systems with simple mappings between symptoms and problems, but diagnostics seldom have simple correspondences for complex equipment and processes. In addition, not all symptoms are necessarily present if a problem has occurred; making other approaches more cumbersome [9].

The concept of context-aware decision making is being carried out by IT, web services, medical fields and pervasive and ubiquitous computing areas [24,25]. The idea is to predict the possible scenarios based on different levels of context using data aggregation by machine learning methods to provide necessary output to the user that is efficient and effective [26]. Apart of being context-aware, the combination of maintenance activities into the context aware is completely new idea that is capable of producing efficient diagnosis and prognosis.

There is a need to be able to quickly and efficiently determine the cause of failures, while minimising the need for human intervention, but the above approaches either take a considerable amount of time before failures are diagnosed, or provide less than reliable results, or are unable to work well in complex systems. This present paper proposes a context-aware hybrid approach to asset health assessment. The system is useful for diagnosis of problems and proposing remedial measures to repair or correct them within time bound manner. The result will be helpful in optimising maintenance scheduling and route planning while minimising downtime arising from unexpected breakdowns. Simply stated, it will provide a way of predicting faults and dealing with predicted faults before they occur [9].

2. Disparate data sources for asset health assessment

Most of the assets have a direct impact on the risk for safety, hazard, shutdown or slowdown of factories, transportation systems or other higher level systems where they are deployed. The health and maintenance of these assets is critical to the effectiveness, efficiency and security of humans, processes and products [1]. Any improvement in the condition or maintenance management and the technology involved in maintenance tasks can have a substantial influence on the operation to provide higher asset revenue.

There is a need to integrate asset information to get an accurate health assessment of the whole system, from sources i.e. infrastructure, factories, facilities, vehicles etc., and thereby determine the probability of a shutdown or slowdown [12]. However, for such complex assets, much information needs to be captured and analysed to assess the overall condition of the whole system. Additionally, the development of a variety of condition indicators that can be used for condition monitoring has resulted in a significant amount of new and useful information for maintenance. A great deal of information provided over a large area can quickly lead to data and information overload and, thus, must be handled carefully.

Moreover, the data collected are often dispersed across independent systems that are difficult to access and not correlated. If the data from these independent systems are combined into a common correlated data source, this rich new set of information could add value to the individual data sources [9]. For example, it is common for most of the facilities to collect work records of where work has been done. Many assets also typically measure their health using condition monitoring (CM) or non-destructive testing (NDT) techniques [27] as "nowcasting" technologies in order to see where work needs to be done. However, these two datasets can remain in separate and individual systems. By combining the data into a location correlated dataset, i.e. metadata (Fig. 1), the quality and/or the effectiveness of the work being performed can be analysed by comparing the "asset health" before and after the work is completed [9,64].

Fig. 2 shows the systems currently used by the maintainers in factories or facilities. Computerized maintenance management system (CMMS) and CM are the most popular repositories of information in maintenance, where most of the deployed technology is installed and unfortunately isolated information islands are usually created [16]. While using a good version of either technology can assist in reaching the defined maintenance goals, combining the two (CMMS and CM) into one seamless system can have exponentially more positive effects on maintenance and asset performance than either system alone might achieve. The combination of the strengths of a top-notch CMMS (preventive maintenance (PM) scheduling, automatic work order generation, maintenance inventory control, and data integrity) with the capabilities of a leading-edge CM system (multiple-method condition monitoring, trend tracking, and expert system diagnoses) in such a way that work orders are generated automatically based on information provided by CM diagnostic and prognostic capabilities improving dramatically the asset performance, [6,11,63].

Just a few years ago, linking CMMS and CM technology was mostly a vision easily dismissed as infeasible or at best too expensive and difficult to warrant much investigation. Now, due to the advancement in computing technologies, combination of CMMS and CM have been possible to carried out to achieve such a link relatively easily and inexpensively. A top-shelf CMMS can perform a wide variety of functions to improve maintenance performance, [13]. It is the central organizational tool for World-Class Maintenance (WCM). Among many other critical features, a CMMS is primarily designed to facilitate a shift in emphasis from reactive to preventive maintenance. It achieves this shift by allowing maintenance professional to set up automatic PM work order generation. A CMMS can also provide historical information which is then used to adjust PM system setup over time to minimize unnecessary or redundant maintenance actions or repairs, while still avoiding